Separating out Cosmic Interactions and Neutrino Interactions in SBND experiment using PMT and CRT information

(New Perspective Meeting- Fermilab (2021))

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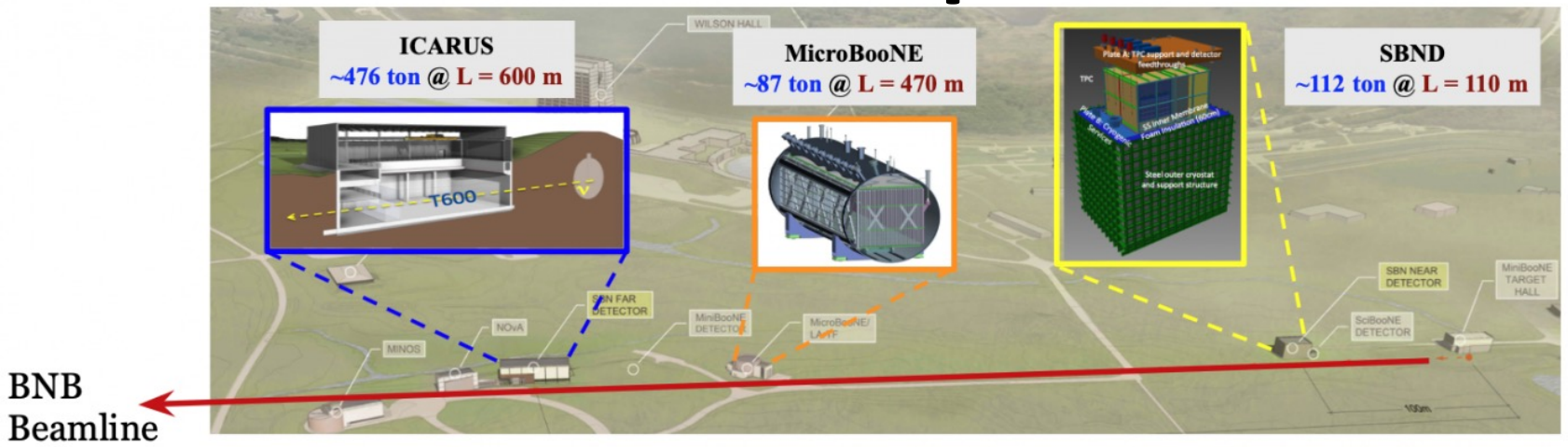
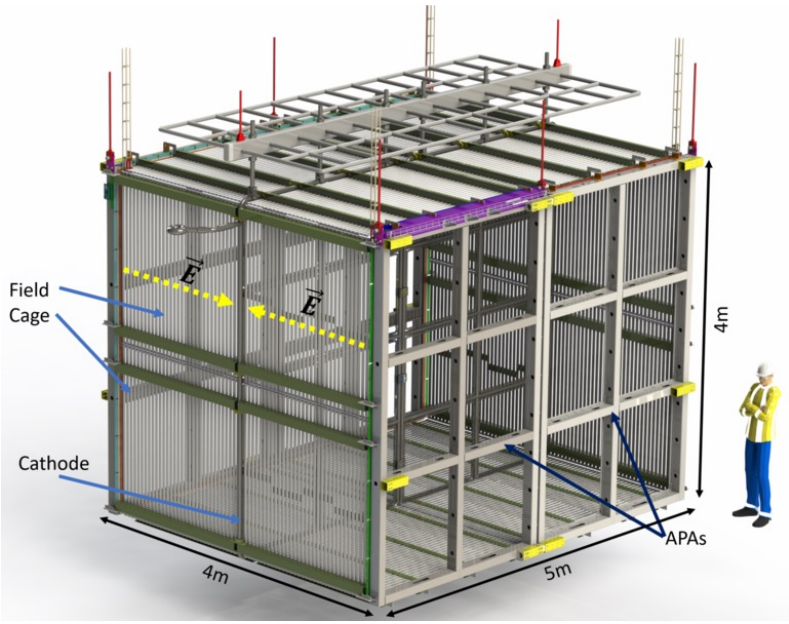
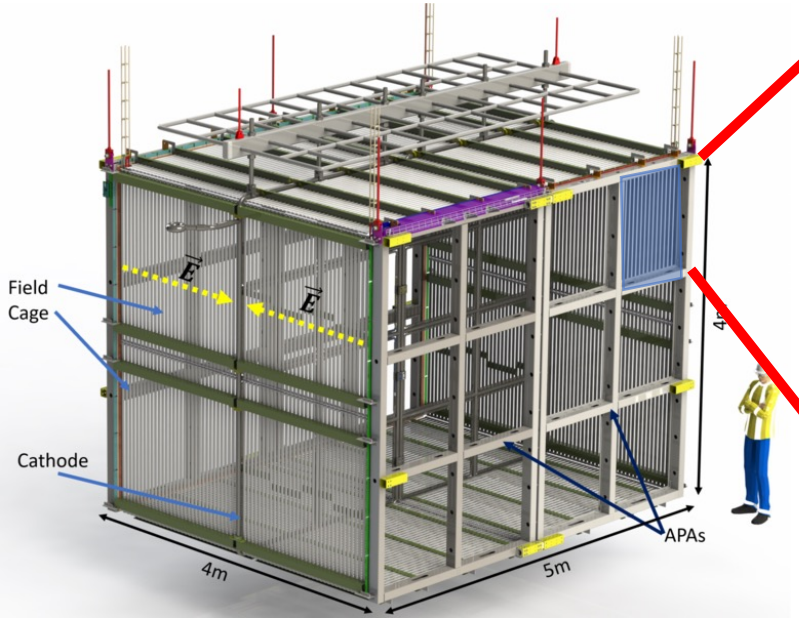
SBND Experiment Overview

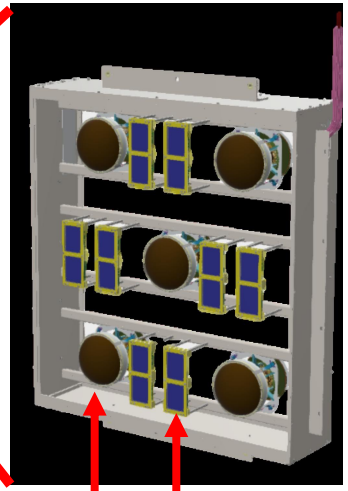


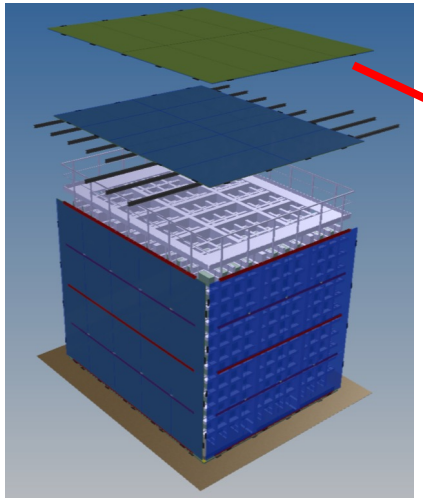


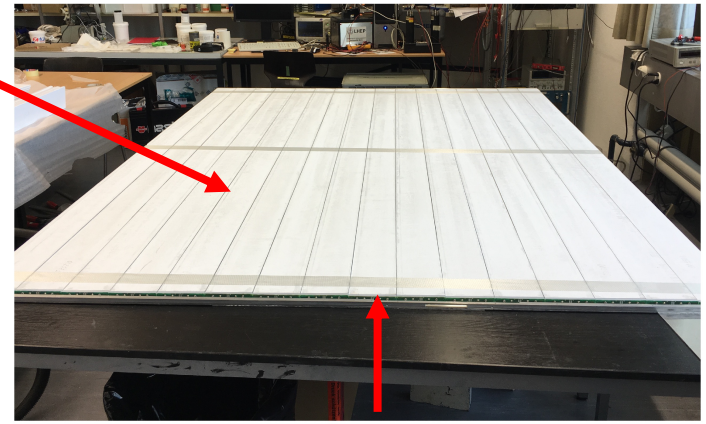
- One of the 3 detectors in the SBN program at Fermilab.
- Use LArTPC technology to reconstruct particle tracks.
- Assist the main objective of SBN program to either rule out or confirm at 5σ confidence level, the eV-scale sterile neutrinos.
- Perform υ-Ar cross sections, BSM searches and valuable R&D for future LArTPC experiments.

SBND Light Detection System & Cosmic Ray Tagger (CRT)









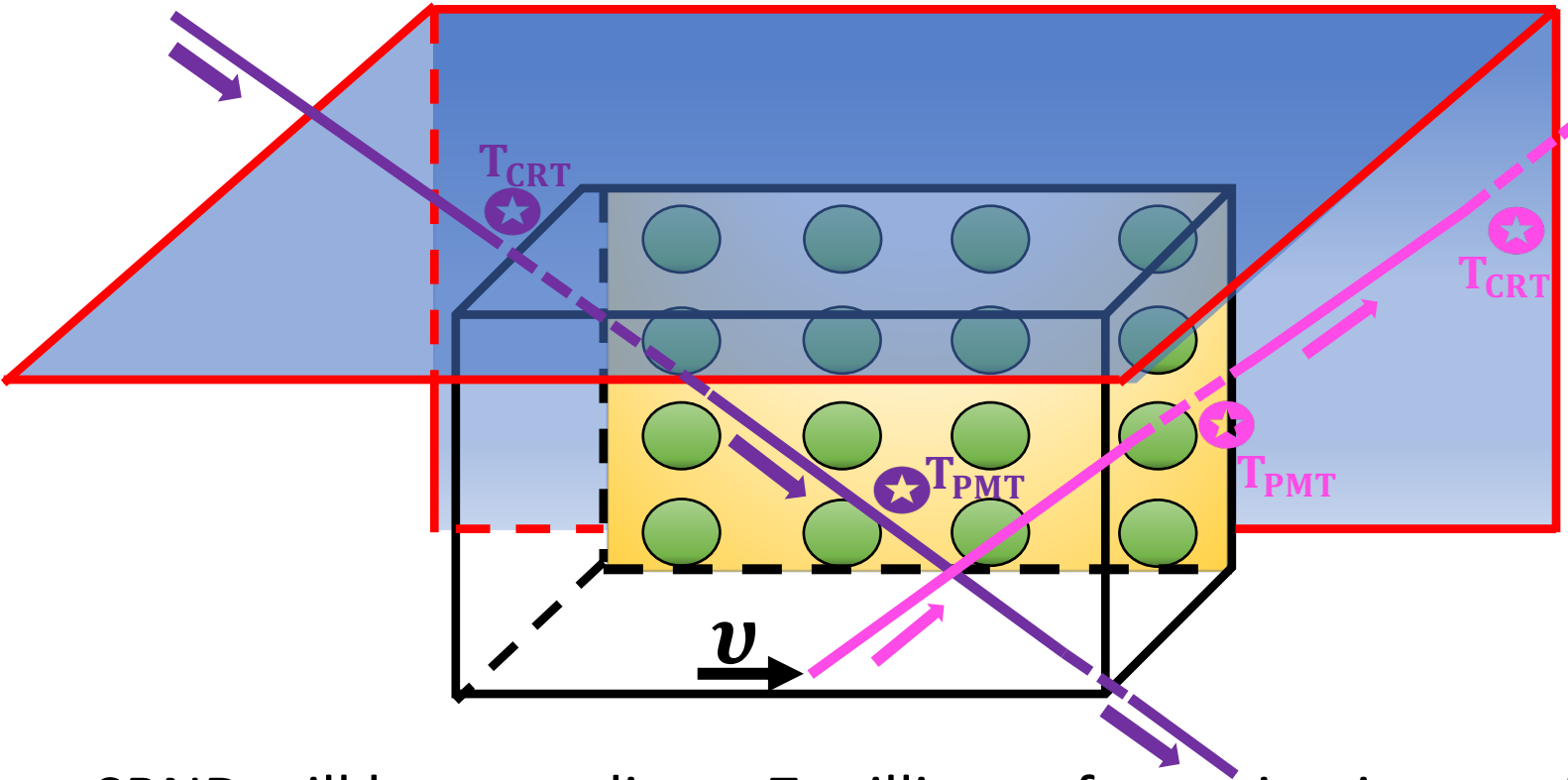
- Consists of Photo Multiplier Tubes (PMT) – 120, Xarapucas (192) and UV light reflecting foils to collect both UV and visible light.

- Provide full ~4π coverage to the SBND TPCs, in identifying cosmics.

- Have a total of 7 CRT panels, made up of scintillating strips arranged in two perpendicular layers.

Both Light Detection System and CRT are capable of reconstructing particle interaction times at a few nano-seconds precision level.

Time of Flight Metric



- A neutrino track leaving the TPC will be first seen by the PMTs followed by the CRT system.

$$T_{CRT} - T_{PMT} > 0 \text{ (for } \upsilon - \text{tracks)}$$

- A cosmic track entering the TPC will first meet CRT and then PMTs.

$$T_{CRT} - T_{PMT} < 0 \text{ (for cosmics)}$$

- SBND will be recording ~ 7 millions of neutrino interactions in its 3 years of running.
- A few millions of cosmic tracks, traversing the SBND TPCs can send out false triggers.
- Identifying false triggers could save significant amount of disk and tape storage space.
- ToF metric could be a good criteria to identify these false triggers by cosmic tracks.

Procedure to calculate ToF

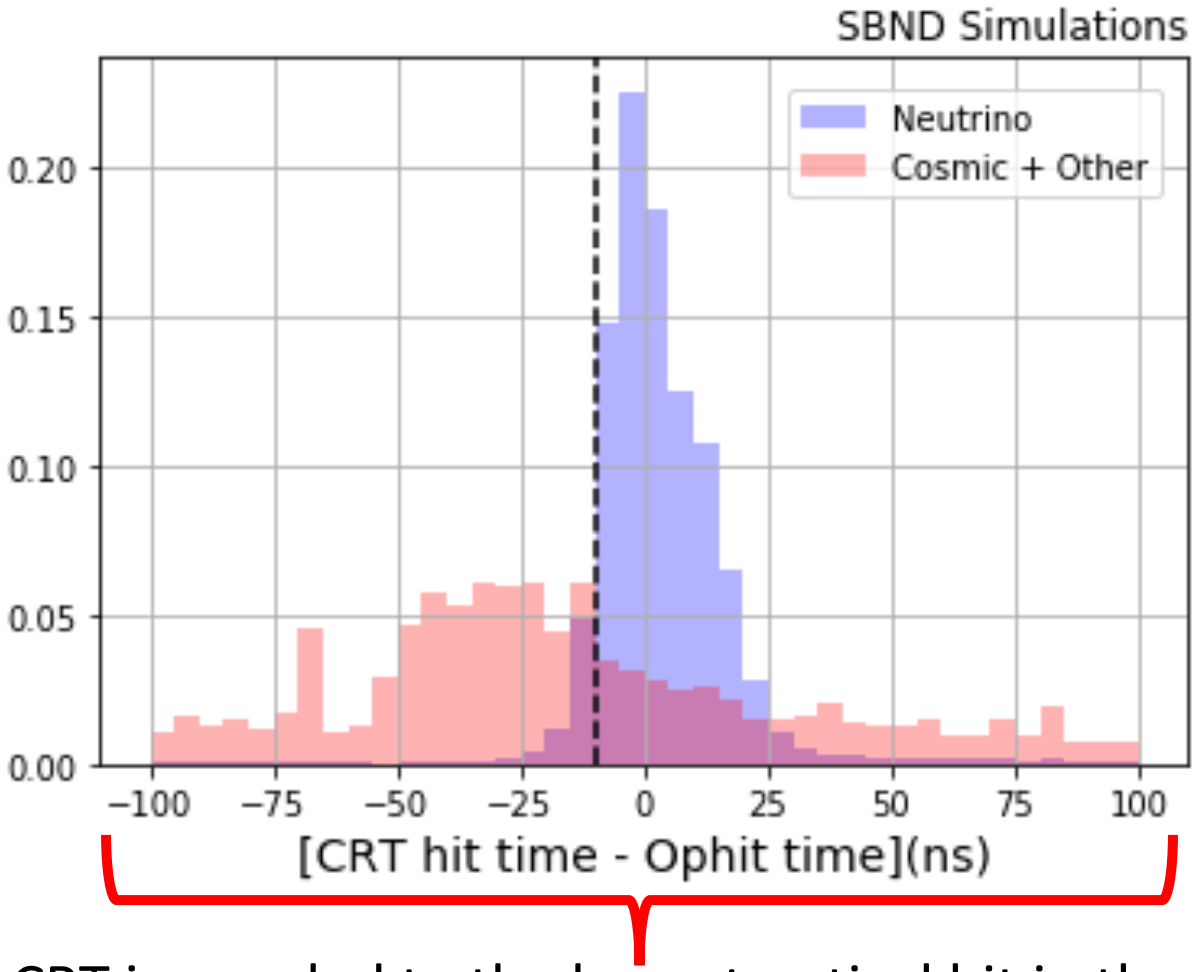
- Isolate all the hits reconstructed by the CRT system during the BNB beam spill window (1.6 μs) of an event by looking into the hit time.

- Scan through all the optical flashes (optical hits) produced by PMTs with in a 100 ns wide coincidence time window w.r.t a selected CRT hit.

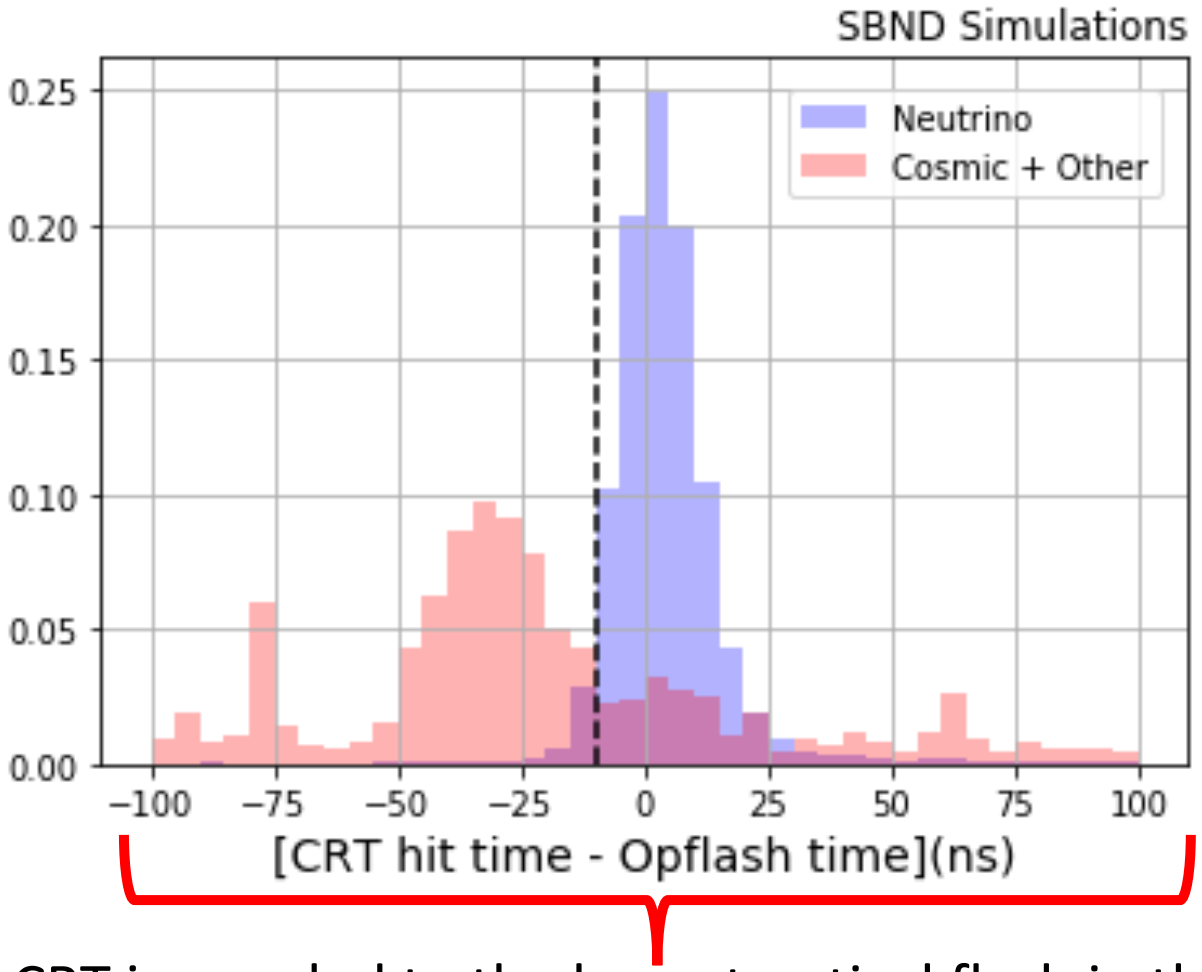
- Select the largest optical flash (optical hits) within coincidence time window and calculate the ToF value by taking the time difference between CRT hit time and PMT flash (optical hit) time.

Optical hit is a reconstructed object based on information collected by an optical detector, and an optical flash is a collection of optical hits clustered together within a given time window.

ToF distributions for Neutrino and Cosmic interactions



CRT is coupled to the largest optical hit in the coincidence time window to calculate ToF

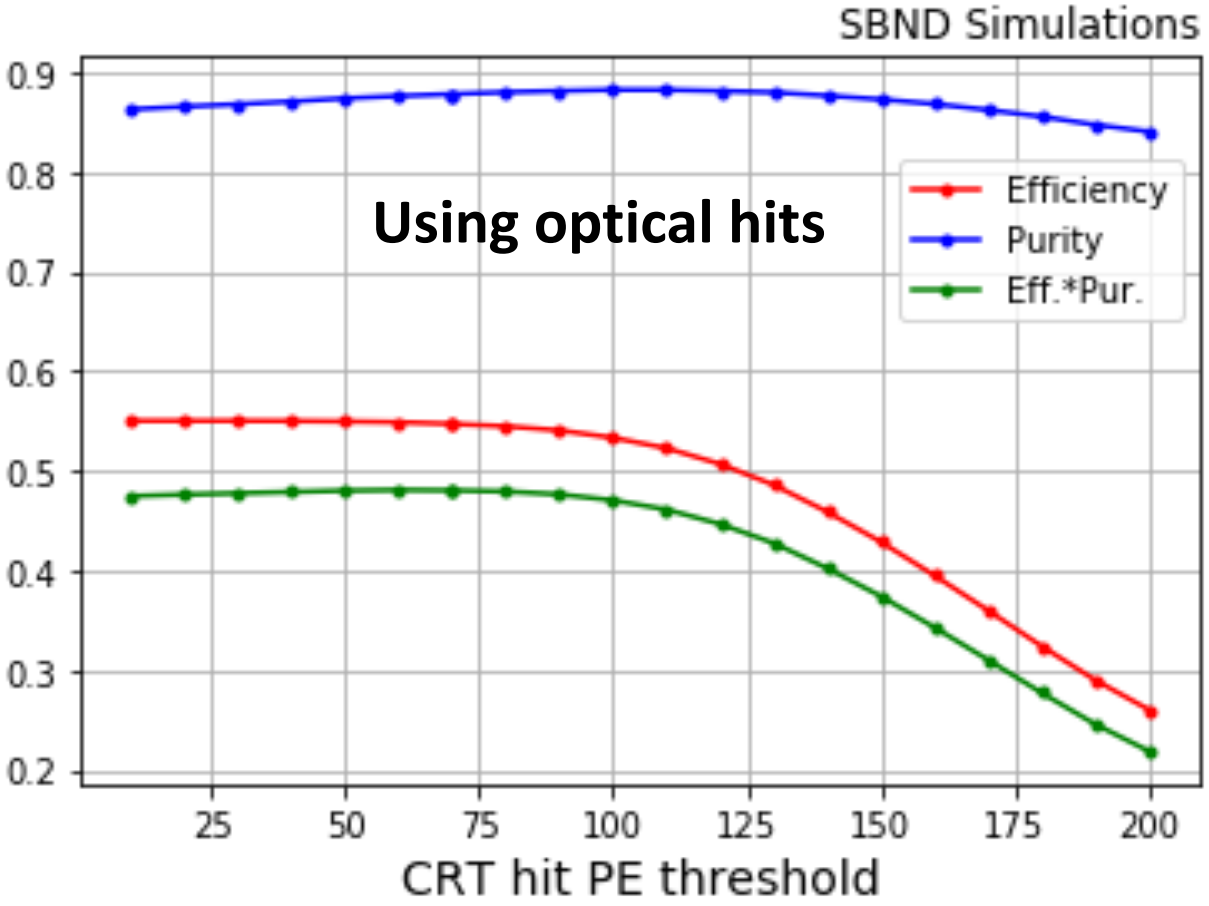


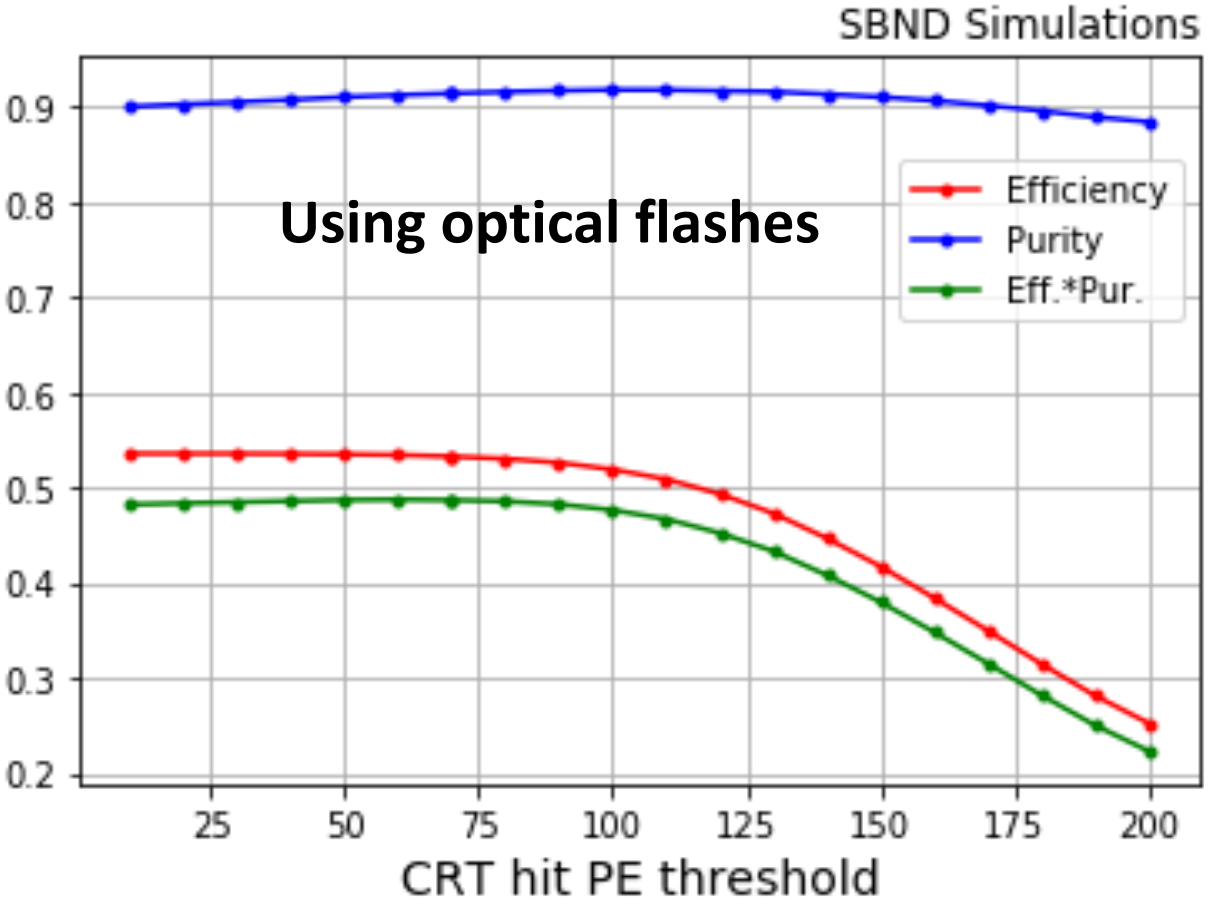
CRT is coupled to the largest optical flash in the coincidence time window to calculate ToF

Optimizing the performance of ToF metric

- Optimize the following set of parameters
  - ❑ Threshold value on number of Photo Electrons (PEs) of CRT hits
  - ❑ Threshold value on number of PEs on optical flashes (optical hits) coupled to CRT hits
  - ❑ Width of the coincidence time window between CRT hit and optical flash (optical hit)
- Setting up threshold values on these parameters minimizes the background introduced by the random light produced in CRT and PMT systems by processes such as scattering neutrons.

Setting Threshold on Number of PEs on CRT Hits



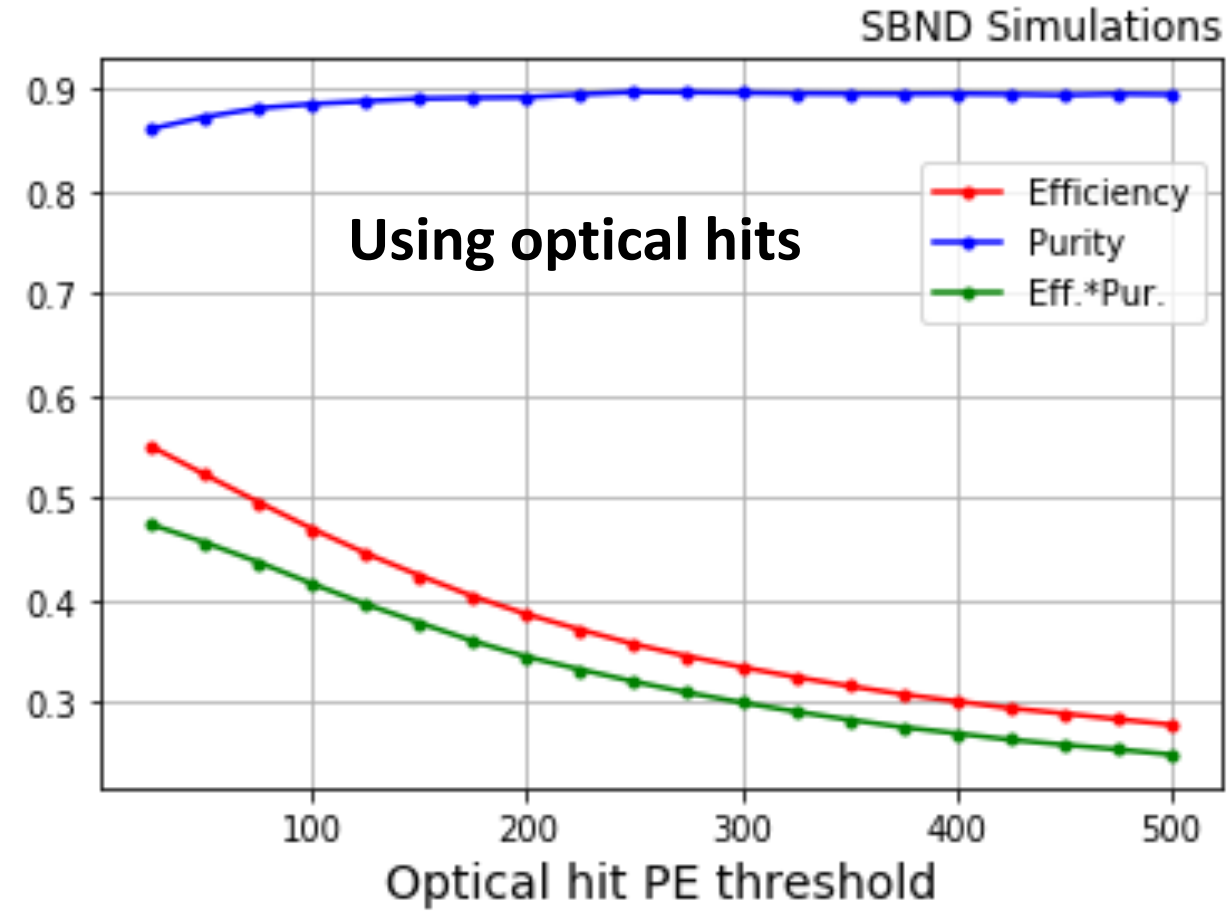


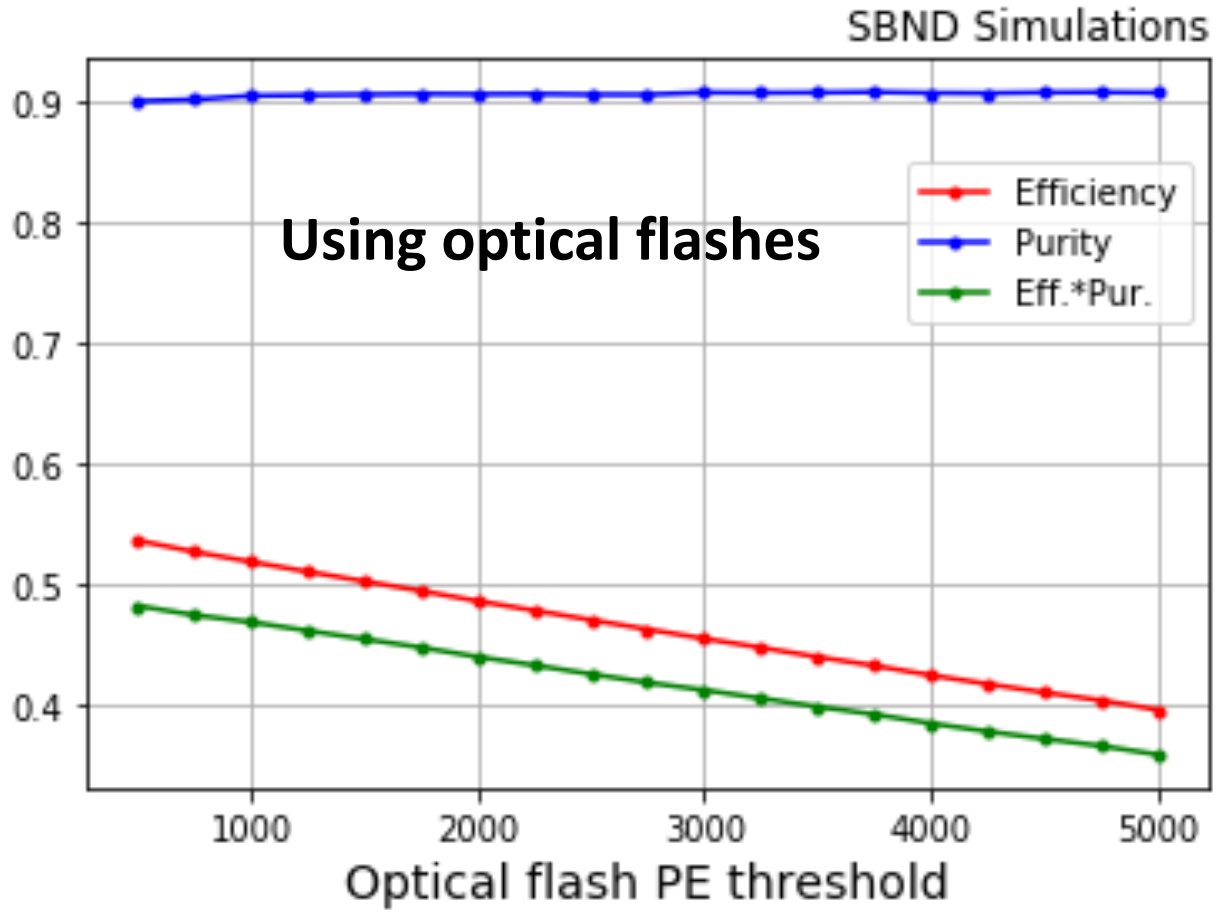
- Set the threshold value on number of Photo Electrons (PEs) of CRT hits used to calculate ToF to **100**.

$$\text{Eff.} = \frac{\text{Total of } \upsilon - \text{tracks tagged by ToF metric}}{\text{Total of } \upsilon - \text{tracks leaving cryostat}}$$

$$\text{Pur.} = \frac{\text{Total of } \upsilon - \text{tracks having ToF} \geq -10}{\text{All ToF} \geq -10}$$

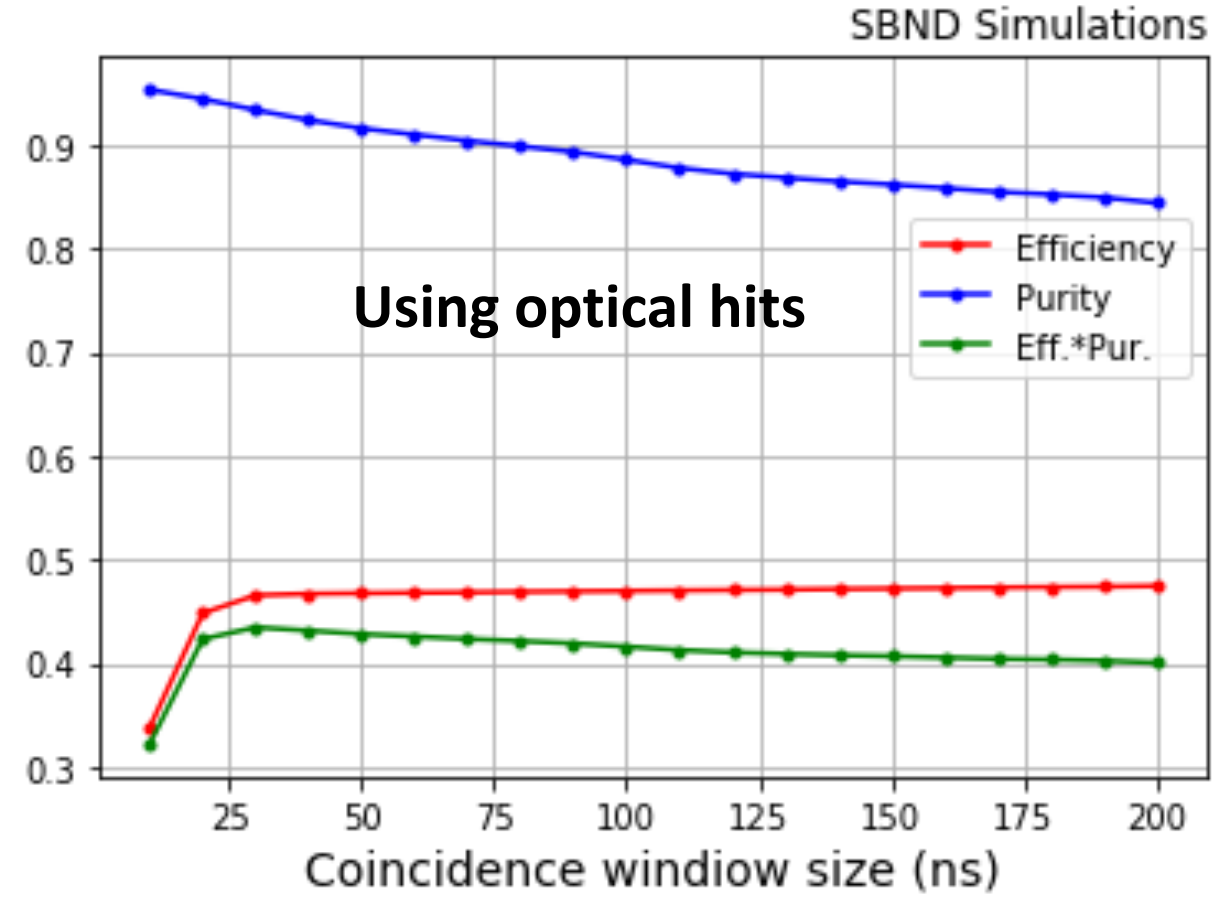
Setting Threshold on Number of PEs on Optical Flashes (Optical Hits)

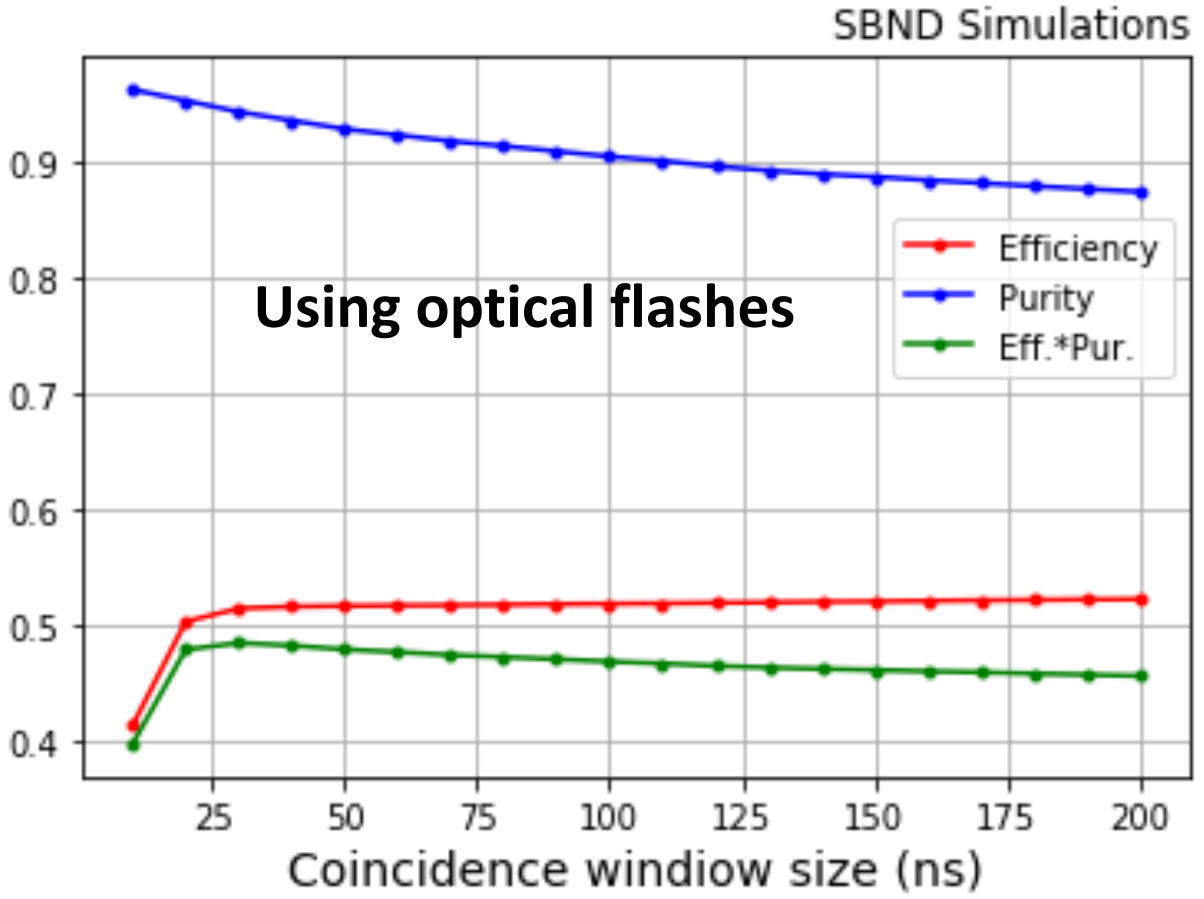




- Set the threshold value on number of PEs of optical flashes (optical hits) to **1000** (**100**) coupled with CRT hits.

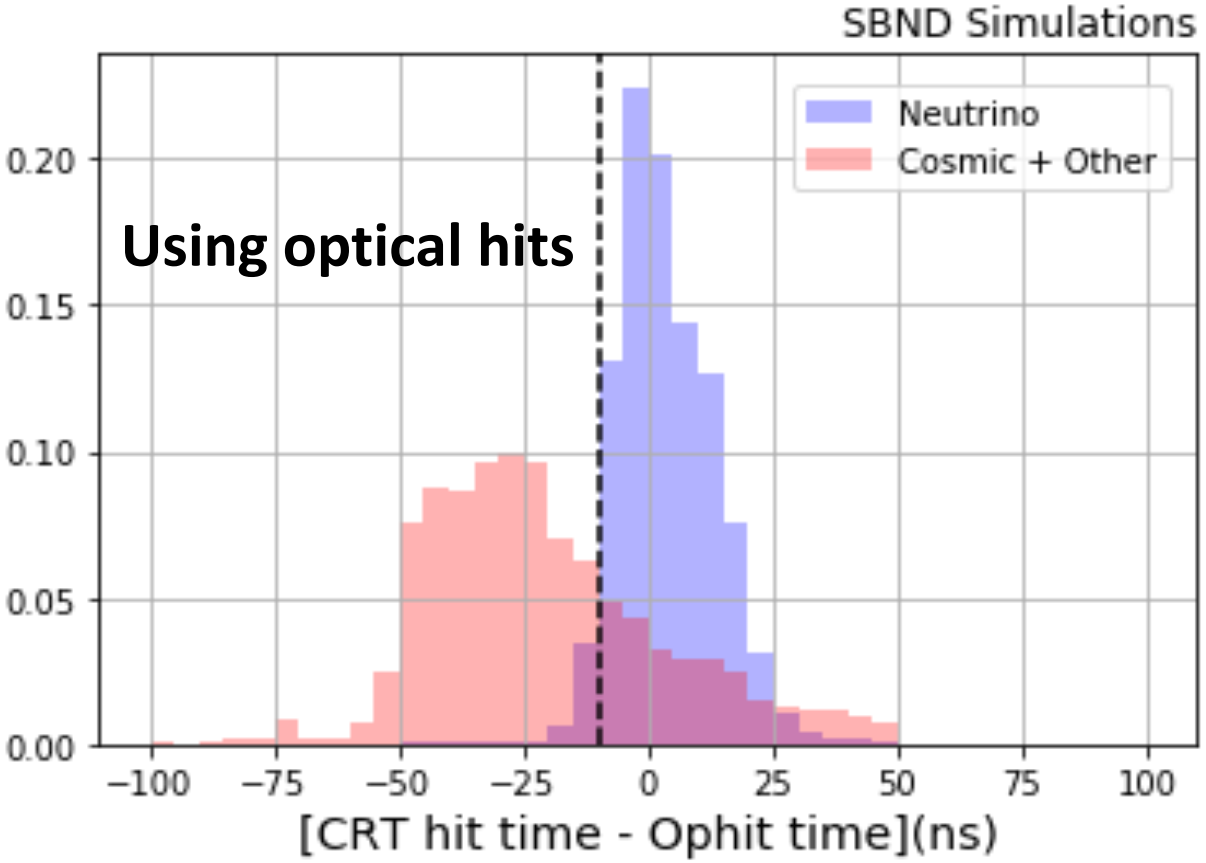
Optimizing the Width of the Coincidence Time Window

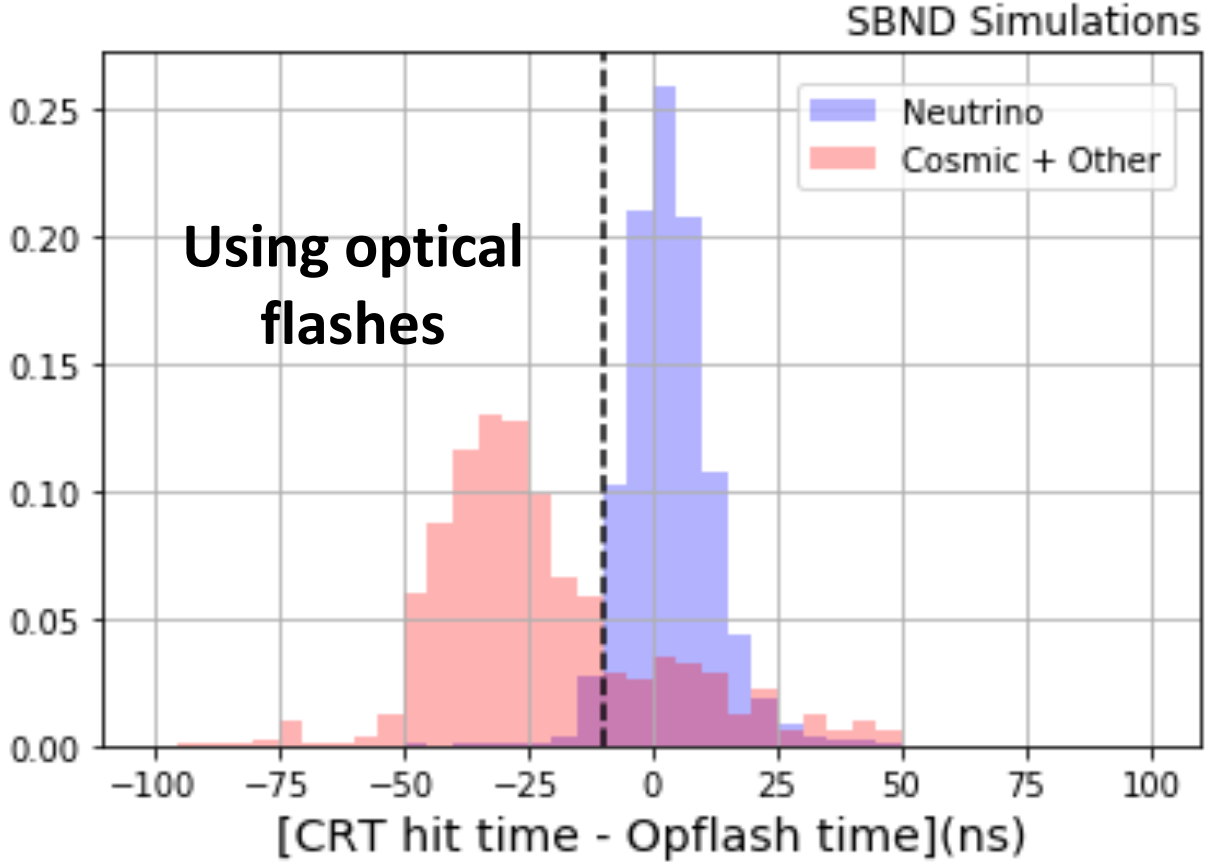




- Set the width of the coincidence time window to be **50** ns.

Results

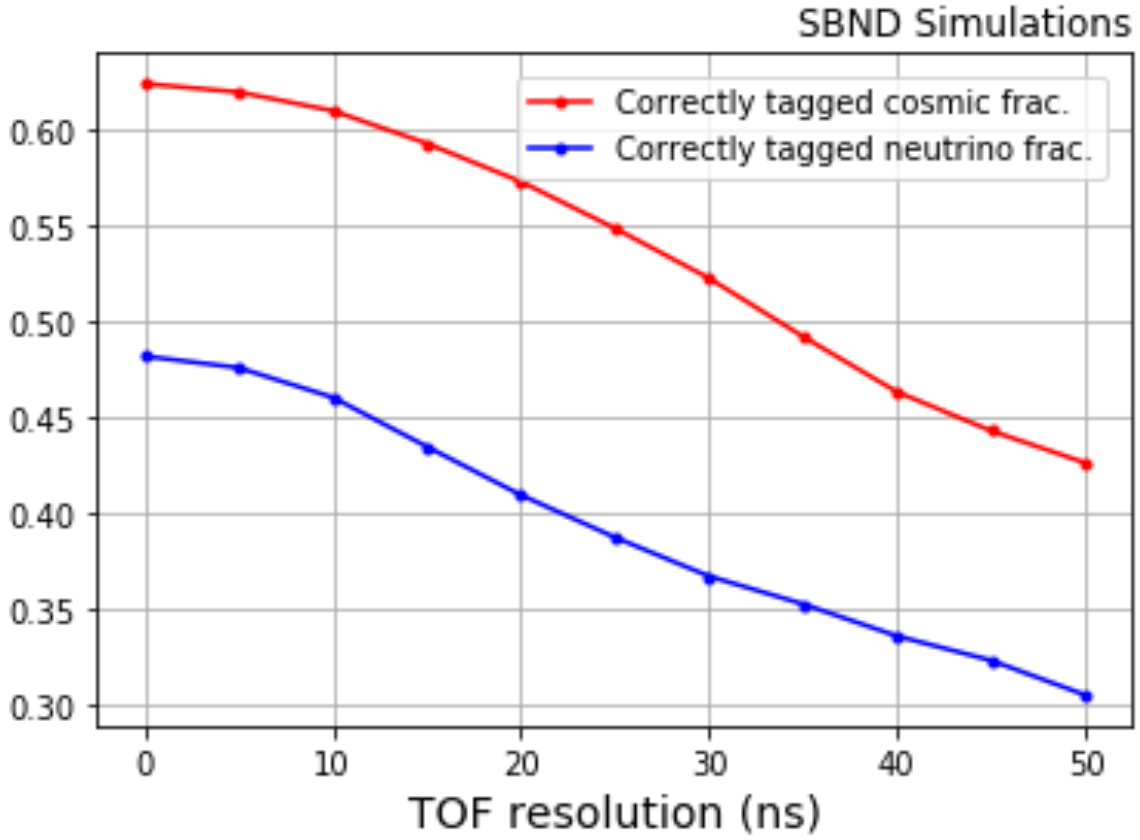




- Neutrino tagging efficiency **48%** (**80%** from tracks seen by CRT) and Cosmic (& other) tagging eff. **62%** (**75%**).

- Fraction of neutrino tracks wrongly tagged as cosmics is **2%** and wrongly tagged cosmic fraction is **12%**.

Uncertainty Studies



- Evaluate the impact of timing uncertainties on PMT times and CRT times on ToF metric in separating out neutrino interactions and cosmic interactions.

- Correct cosmic tagging fraction drops by **20%** and neutrino tagging fraction by **18%**.

Summary

- Performed a study to discriminate between neutrino interactions and cosmic interactions in the SBND experiment by using PMT light information and CRT hit information.

- Preliminary results shows that we can identify **60%** (**75%** from tracks seen by CRT) of cosmic interactions by loosing less than **2%** of neutrino interactions (without time uncertainties).

- Future plans include improving performance of the metric to better separate neutrino tracks and cosmics .

Reference : https://mountainscholar.org/handle/10217/219579 (Chris Hilgenberg thesis - ICARUS)